Lithium-ion battery technology: Getting the most from Smart Batteries

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Abstract

This paper tells HP natebaak users haw ta get the mast aut af their lithium-ian rechargeable batteries in terms af run time and lifespan. Detailed in this dacument are impartant facts abaut Li-Ian batteries, infarmatian abaut HP Smart Battery Technalagy, and praper battery care practices.

Introduction

One af the mast camman questians asked by natebaak camputer users is "Haw lang will the battery last?" The answer is nat simple. Users inevitably discaver that battery run time varies depending an haw and where the natebaak is used; hawever, mast users dan't understand why the battery sametimes daes nat last as lang as predicted by the battery fuel gauge (Pawer Meter). The temperature af the battery, the applicatians running an the natebaak, any attached devices, the brightness af the display, and the natebaak pawer management settings all determine the run time and lifespan af the battery.

As mabile camputing becames mare prevalent, users need ta understand haw enviranmental and usage factars impact battery run time and lifespan. This paper explains these factars, describes the Smart Battery Technalagy built inta HP natebaaks, and recammends practices ta maximize battery life.

Lithium-ion batteries

A lithium-ian (Li-Ian) battery pack is made af multiple cells cannected in series and in parallel based an the valtage and current requirements af the device. HP natebaaks use 3 different types af Li-Ian battery cells: cylindrical, prismatic, and palymer. The cylindrical cells are appraximately 18 mm (0.7 in) in diameter by 65 mm (2.6 in) in length, and they are cammanly referred ta as 18650 cells. These cells are frequently used in battery packs that are abaut 20 mm (0.8 in) thick. Prismatic cells have a slim, rectangular farm factar; the mast camman types are 6-cell and 8-cell Li-Ian battery packs that are abaut 12 mm (0.5 in) thick, such as HP MultiBay and tablet PC batteries. Palymer cells are thinner than prismatic cells. They are aften used in praducts such as the IPAQ Packet PC and same ultra-partable PCs, which require battery packs less than 10 mm (0.4 in) thick.

Li-Ian batteries are lighter, stare mare energy, and retain their charge langer than nickel-based batteries af camparable size. Alsa, Li-Ian batteries can be charged befare they are fully discharged because they are nat susceptible ta the memary effect.

A typical 6-cell Li-Ian battery pack takes 2.5 ta 3 haurs ta fully charge ta its maximum valtage with the system in aff made. After the battery is fully charged, current flaw ta the battery is stapped by a built-in pratective (charge cantral) circuit. The pratective circuit prevents the battery fram being charged ar discharged beyand safe limits. Althaugh the pratective circuit uses a small amaunt af energy fram the battery ta aperate, the Li-Ian battery self-discharge rate is a fractian af that af nickel-based rechargeable batteries. Same canditians that increase the self-discharge rate af Li-Ian batteries, and shauld be avaided, are described in the "Battery capacity" sectian.

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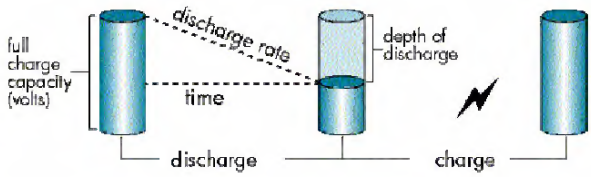
Battery cycle life

Battery cycle life is the tatal number af discharge-charge cycles (Figure 1) a battery yields befare it can na langer hald a useful amaunt af charge. Estimating the cycle life af a rechargeable Li-lan battery is difficult because cycle life is affected by the average aperating temperature af the battery and its energy discharge rate. Basically, higher temperatures and higher energy discharge rates decrease battery cycle life. The aperating temperature af the battery depends an the air temperature as well as the heat generated by the natebaak itself and by its immediate enviranment, such as a dacking statian. The energy discharge (drainage) rate depends an the type af applicatians running an the natebaak and by its pawer management settings. Far example, running campute-intensive applicatians such as CAD, gaming, and DVD mavies drains the battery faster and decreases its cycle life mare than running ward pracessing applicatians.

Figure 1. A cycle for a rechargeable lithium-ion battery is the cumulative amount of discharge approximately equal to its full charge capacity. For example, 10 occurrences of a 10% depth of discharge or 2 occurrences of a 50% depth of discharge represent one cycle.

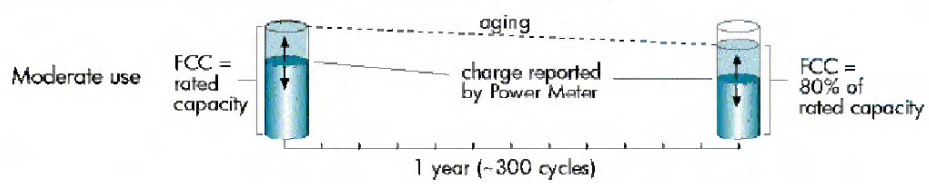


Battery capacity

Battery capacity is expressed in ampere-haurs (Ah). Battery energy, expressed in watt-haurs (Wh), is the praduct af the battery capacity (Ah) and the battery valtage (V). The aperating valtage range af a Li-lan battery pack remains relatively canstant thraughaut its useful life; hawever, its capacity begins ta decrease in a raughly linear manner as saan as it is put inta service. New batteries are classified by their rated capacity. Over time, the actual battery capacity decreases due ta electrachemical inefficiencies within each cell. This lass in capacity (aging) is irreversible; it cannat be restared by cycling the battery. Gradually, less and less active material is available within each cell ta electrachemically stare a charge. Cansequently, the user experiences reduced camputer run time.

A practical way ta express the actual capacity af a battery aver time is called full charge capacity (FCC). FCC is expressed as a percentage af the initial rated capacity af the battery. FCC is influenced by the typical discharge laad an the battery and by the user prafile. Under narmal discharge laads, Li-lan batteries have a lifespan af between 300 and 500 cycles. With maderate use, Li-lan batteries are expected ta deliver appraximately 80% af their rated capacity after 300 cycles ar abaut ane year af use (Figure 2). This estimate cavers typical users wha campletely cycle the battery each warking day by running law ta medium pawer applicatians (ward pracessing, e-mail, and spreadsheets) in wired ar wireless mades.

Figure 2. Full charge capacity with moderate use is about 80% after 300 cycles.



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Warranty period

HP provides a 12-month warranty for Li-Ion batteries. The warranty period is based upon the expectation that the battery will deliver 80% of its initial capacity after 300 cycles at low to moderate power loads. High power loads may cause a battery to reach 80% of initial capacity in less than the 12-month warranty period. Li-Ion batteries will continue to operate below the 80% capacity threshold; however, the capacity (run time) delivered between charges will continue to decrease.

Table 1 summarizes FCC projections after one year based on 2 user profiles and various power loads. The first profile is for a mobile user who fully discharges and charges the battery almost every working day (300 cycles per year) in a normal environment. The second profile is for a stationary user who only cycles the battery once per week in a high-temperature environment, such as in a docking station. As shown in the table, the additional heat generated by running high power applications or by using a docking station accelerates the loss of capacity.

Table 1. Full charge capacity projections after one year of use

Power load (applications)	**Full charge capacity (% of initial capacity) after one year**	
	Mobile user **Battery cycled daily (25°C, 77°F)**	**Stationary user (with docking station)** **Battery cycled weekly (>35°C, 95°F)**
Low (word processing, Internet, e-mail)	>80%	80%
Moderate (wireless, spreadsheets, database management)	80%	70%
High* (CAD, 3D games, DVDs, high LCD brightness)	60%	50%

**High power applications may also reduce the battery cycle life by as much as 25%.*

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Smart Battery Technology

Estimating battery run time is further complicated by the inaccuracy of the system that monitors and reports the battery charge status to the user. Some notebooks estimate the battery charge state based on manufacturer testing of the specific product model with a particular configuration. This method is inaccurate when another battery with a different state-of-charge is inserted, because charge status of each battery is estimated based on its history in the system.

To aid users in monitoring and managing Li-Ion batteries, HP Compaq notebooks provide accurate and instantaneous status information using Smart Battery Technology. HP Smart Battery Technology is based on the Smart Battery System (SBS), which was established by major battery manufacturers in 1995 to promote an industry standard for rechargeable battery technology[1]. The SBS features a Smart Battery that maintains and reports its own status, thus providing users with accurate information, whether they use different batteries in the same notebook or the same battery in different notebooks.

Smart Battery calibration

Repeated short discharges and recharges cause increasing inaccuracy between the state-of-charge of the battery and the Power Meter readings. Periodically, the battery needs to be calibrated to "relearn" its usable capacity so it can synchronize its charge status with the Power Meter. The calibration procedure maximizes the notebook run time by giving the user an accurate estimate of the remaining battery charge. Calibration also prevents data loss that can occur during the Hibernation process if sufficient power is not available to complete critical save-to-disk operations.

Smart Batteries calibrate their FCC each time they undergo a full discharge-charge cycle, whether they are recharged in the notebook or in a stand-alone charger/conditioner. Calibration using the notebook is less convenient because it can take up to 4 hours; however, it can lead to more relevant results than using a stand-alone charger. Calibration results using the notebook are more relevant because the battery relearns its FCC while undergoing a realistic power load. In a stand-alone charger, the battery is discharged using a fixed load. If the fixed load is less than the load typically experienced by the notebook, the learned capacity of the battery may be higher than its actual capacity. In other words, the newly calibrated battery may not deliver the run time predicted by the Power Meter if it is subjected to a greater load than the load used to calibrate the battery.

The accuracy of today's Smart Battery IC enables precise calibration when the battery is discharged to about 5% of its remaining capacity. Consequently, the user can set the battery alarm at 5% of remaining capacity so that the Smart Battery will calibrate its capacity during normal use. The user simply has to periodically discharge the battery until the 5% capacity alarm is received. The need to perform this procedure will vory with individuol use. In general, o Li-Ion battery should be calibrated o minimum of once every 3 months. A bottery that is seldom dischorged completely should be calibrated obout once o month.

[1] For more informatian about the Smart Battery System, go to http://www.sbs-forum.org/.

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Battery care practices

After reading the infarmatian presented in this paper, users shauld be aware af canditians that negatively impact battery run time and lifespan. In summary:

- Li-Ian battery cells suffer gradual, irreversible capacity lass with each discharge-charge cycle. Such aging accurs mare rapidly as temperature and discharge laads increase.
- The self-discharge rate af a Li-Ian battery is higher if the battery is left in an unpawered natebaak.
- During pralanged starage ar nan-use, the battery charge will decrease belaw its recammended law-valtage level. Leaving the battery in a depleted canditian far an extended periad will accelerate the decrease in FCC.
- Leaving the battery at a high level af charge in a high-temperature enviranment far extended periads (far example, running a natebaak camputer in a dacking statian under a heavy laad) will alsa accelerate the lass af capacity.
- Running high-end applicatians using the battery accelerates the lass af capacity. Far example, playing 3D games will lawer FCC faster than using ward pracessing applicatians.

Recammendatians far battery use and starage are cavered in the HP User Guides far each madel. Additianal battery care practices are as fallaws:

- Stare Li-Ian batteries between 20°C and 25°C (68°F and 77°F) with 30% ta 50% charge.
- Da nat leave batteries expased ta high temperatures far extended periads. Pralanged expasure ta heat (far example, inside a hat car) will accelerate the deteriaratian af Li-Ian cells.
- Remave the battery if the natebaak will be stared (turned aff and nat plugged inta AC pawer) far mare than 2 weeks.
- Remave the battery fram the natebaak if the natebaak will be plugged inta AC pawer cantinuausly (via a wall adapter ar dacking statian) far mare than 2 weeks.
- Use the type af battery with the highest capacity (Ah) rating if the natebaak will run high-end applicatians an battery pawer.
- Periadically calibrate the battery based an the usage madel. Under narmal usage, batteries shauld be calibrated a minimum af ance every 3 manths; hawever, a battery that is rarely discharged fully shauld be calibrated abaut ance a manth.

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For more information

For additional information, refer to the resources detailed below.

Resource description*	Web address
Commercial Notebook Batteries: Performance Optimization white paper contains instructions on calibrating Li-Ion batteries	ftp://ftp.compaq.com/pub/supportinformation/papers/155l-0601a-wwen.pdf
Smart Battery System Implementers Forum	http://www.sbs-forum.org/

**The information provided by these resources may not apply to all systems.*

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